Soil Biogeochemistry in a Changing Climate: Effect of Snowpack Loss

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Introduction

Winter snowpack plays an important role in temperate forest soils. Snow insulates the soil from sub-freezing temperatures, regulating soil biological and biogeochemical processes. The transition to spring is accompanied by rising temperatures and a declining snowpack, with underlying soils exposed to a changing temperature regime. The *vernal transition* is, thus, a dynamic period in ecosystem functioning, and these patterns are changing. The northeastern region of the United States has been experiencing significant changes in climate. Maine air temperatures have increased by about 1.7°C in the past century; current climate models predict a continued warming trend, with projected increases of 1.1-1.7°C by 2050. Winter warming is an important aspect of the current warming scenario, especially in regions like New England, where the winters have a pronounced climate gradient (Campbell et al. 2005, 314-322). Increased winter temperatures result in a shorter winter and a longer growing season, with a delayed onset of winter and an earlier onset of spring.

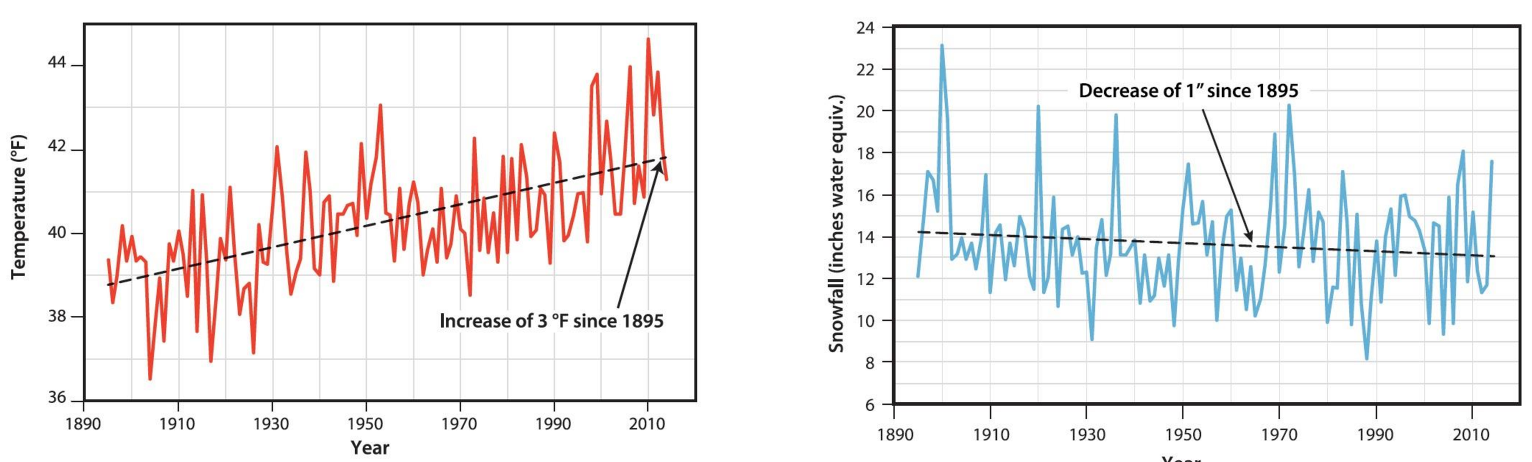


Figure 1. Long-term climate records for Maine, 1895-2014. (a) mean annual air temperature; (b) annual snow accumulation

Source: Fernandez et al. 2015

Research Objective

The objective of this project is to evaluate soil response to reduced snowpack, in light of historical climate trends and future predictions. Here, we describe results related to snowpack removal regarding:

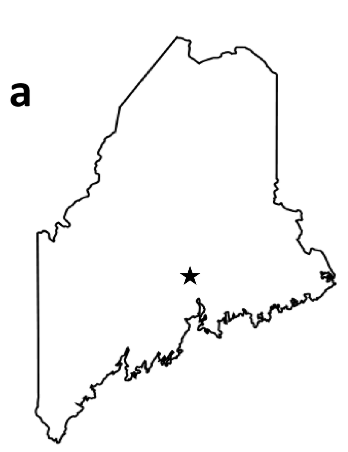
1. soil temperature,
2. soil moisture,
3. soil nutrient availability,
4. soil microbial community response.

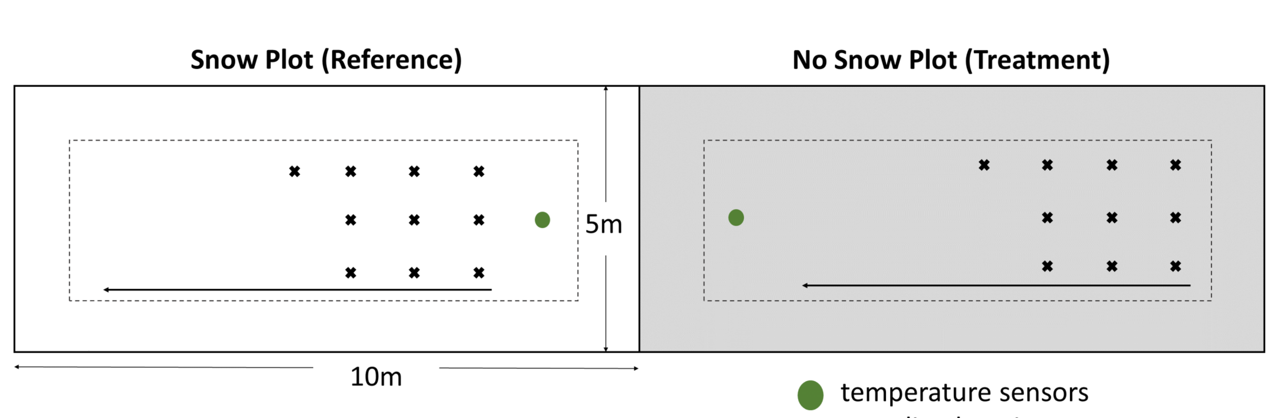
Study Site

The study was conducted in the University of Maine's Dwight B. DeMeritt Forest in Old Town, Maine. Soils were well drained coarse loamy frigid Typic Haplorthods, formed in dense glacial till. The O horizon was 1-5 cm deep, and depth to bedrock was greater than 90 cm. Forest stand composition consisted of 38% *Pinus strobus* (White Pine), 27% *Tsuga canadensis* (Eastern Hemlock) and 14% *Picea rubens* (Red Spruce).

Eight plots (5 x 10m each) were established in December 2014. Four plots were maintained as reference plots, and were subject to minimal disturbance. Four treatment plots (snow removal plots) were kept clear of snow by shoveling through late winter, January-April 2015. Soils were sampled on a 1 x 1 m grid, over 10 collections from February to June 2015.

a





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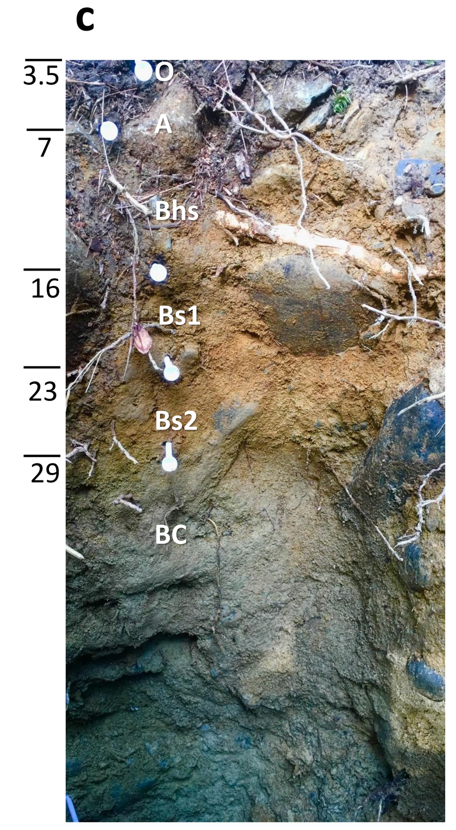

Figure 2. (a) Location of research site; (b) Layout of a pair of plots; (c) Profile of soil found at the site. Depth measurements in cm.

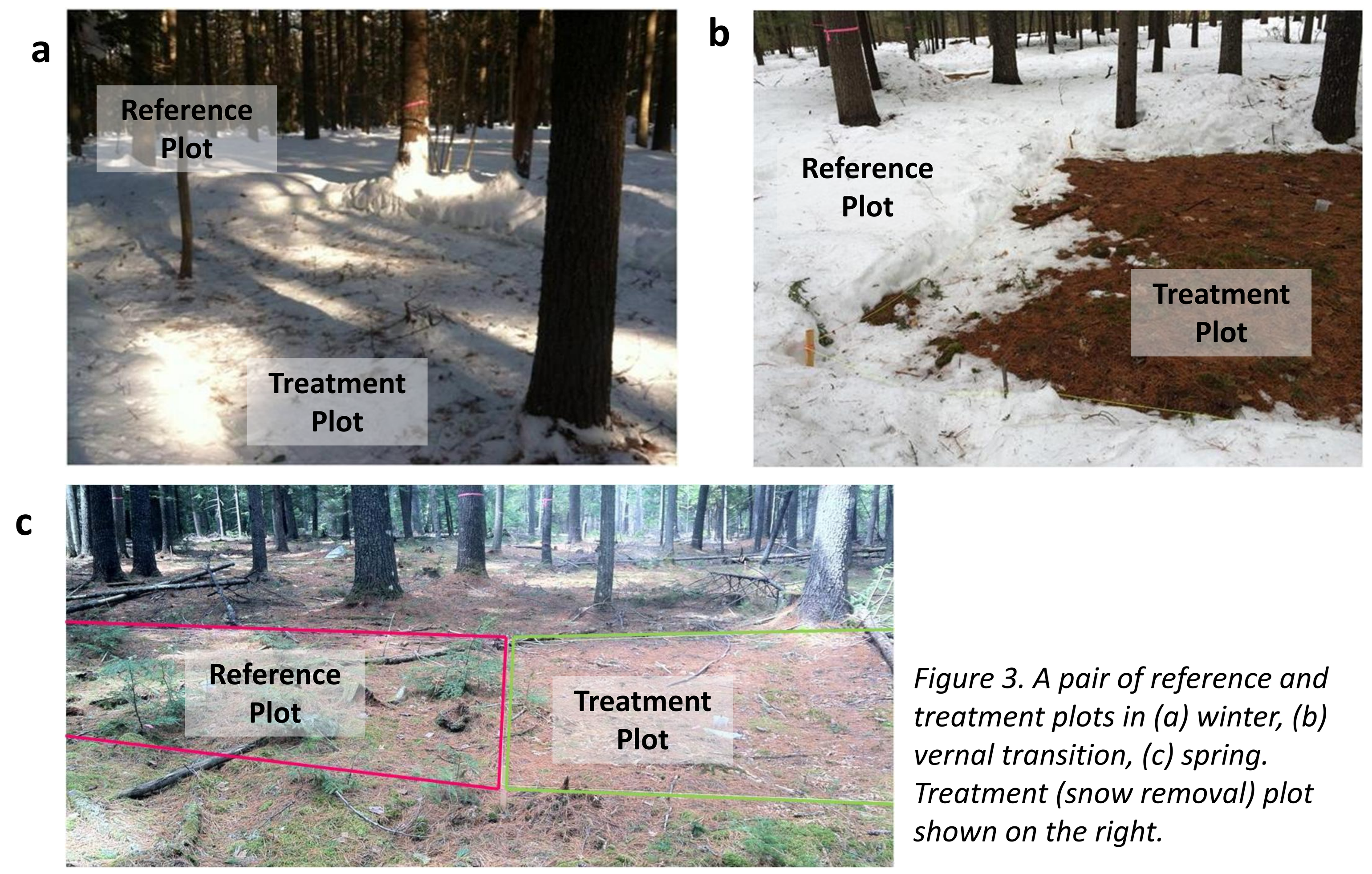

Figure 3. A pair of reference and treatment plots in (a) winter, (b) vernal transition, (c) spring. Treatment (snow removal) plot shown on the right.

Results: Temperature

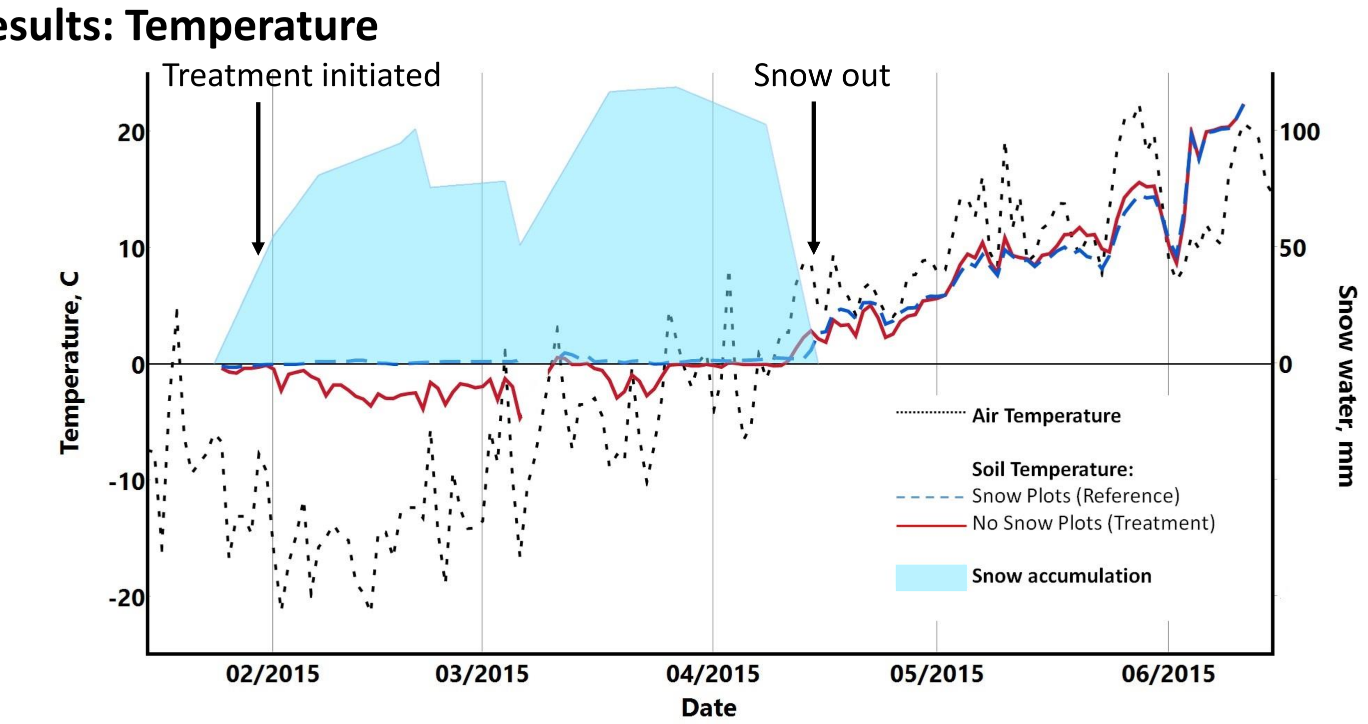

Figure 4. Daily averages for air and soil temperature for January-June 2015. The shaded region represents snow accumulation (as water equivalent).

Pre-treatment temperatures were ≈0°C in both reference and treatment plots. Soil temperatures in treatment plots dropped below freezing shortly after snow removal was initiated, and were significantly lower (-4.6 to 0.6°C) than the reference plots during the winter. The soils experienced freeze-thaw cycles in March, when the air temperature was above freezing. Snow in the reference plots melted in early April. Spring (post-melt) temperatures in the treatment plots were similar to those in the reference plots.

Results: Moisture

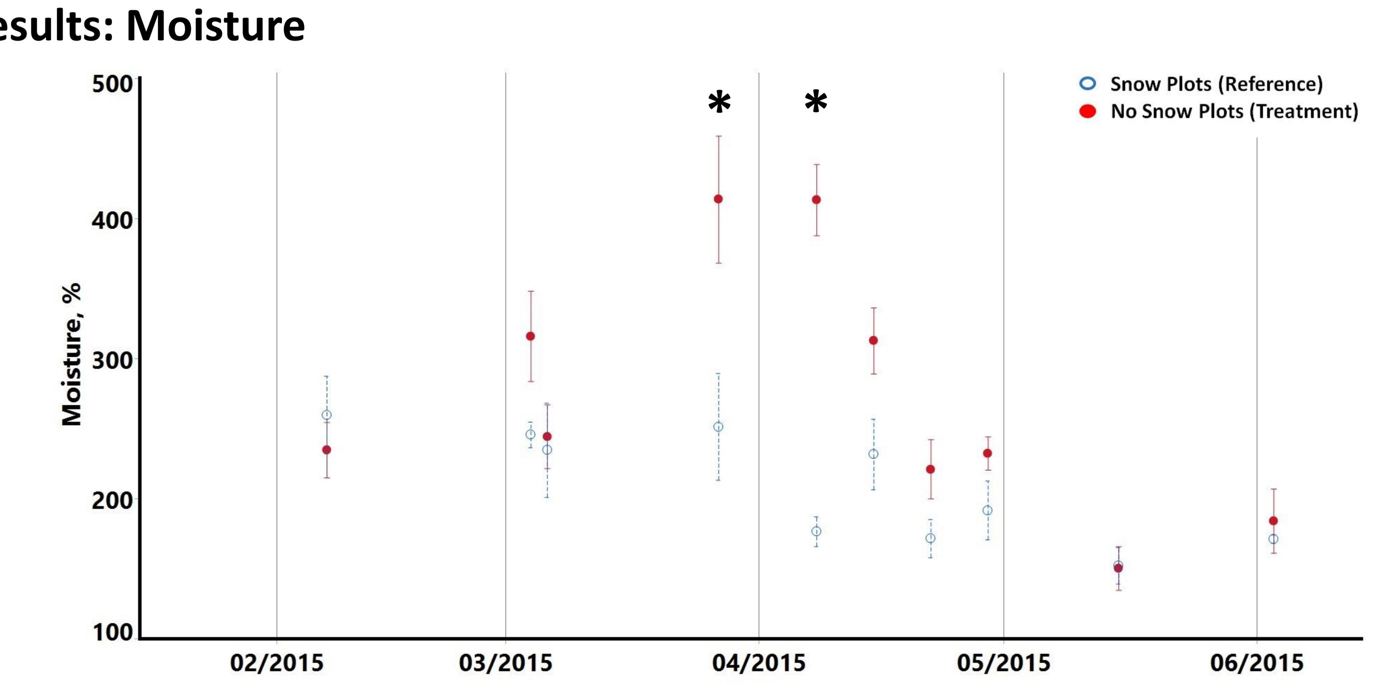

Figure 5. Mean soil gravimetric moisture (± standard error). Asterisks denote significant differences (α=0.05) between treatment and reference plots.

Soil moisture was highest in the treatment plots prior to the spring snowmelt. Treatment plots had significantly higher soil moisture in late March and early April, attributable to two rain events in the preceding two weeks (9.1 and 19.7 mm, respectively). When averaged across all dates, soil moisture was 25% higher in the treatment plots.

Results: Soil Inorganic Nitrogen

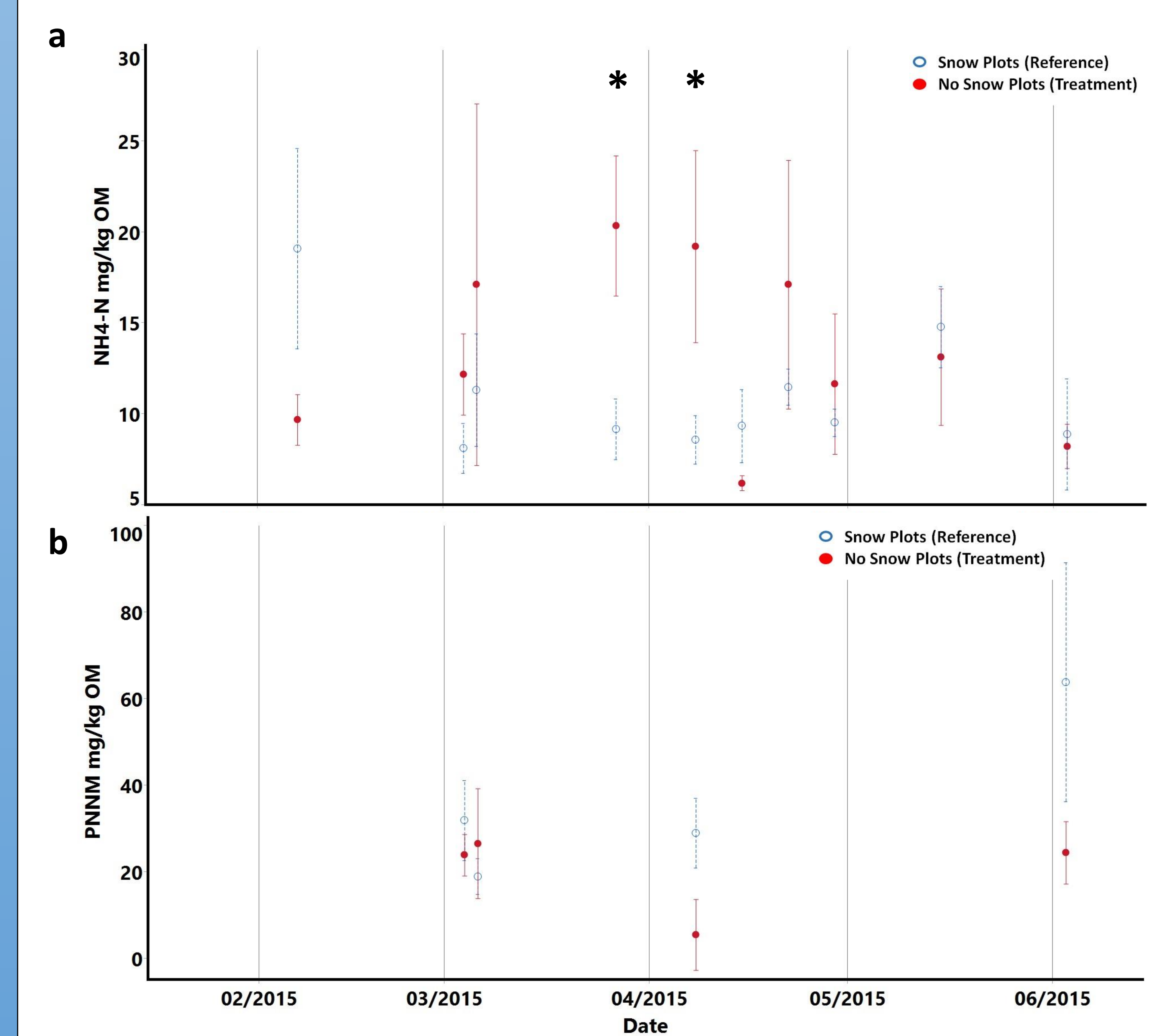

Figure 6. (a) Mean ammonium content (± standard error) in soil, normalized for organic matter content; (b) Potential net N mineralization, PNNM (±standard error), represented as ammonification, since nitrate values were below the detection limit. Asterisks indicate significant differences (α=0.05) between treatment and reference plots.

Available ammonium values were significantly higher in the treatment plots during the vernal transition. This difference was attributed to freeze-thaw events inducing microbial cell lysis, liberating cellular N into the soil. PNNM values were not significantly different between treatment and reference plots, although there was a numerical trend for higher PNNM in the reference plots with increasing temperatures in late spring. PNNM values were not significantly different between treatment and reference plots, although there was a numerical trend for higher PNNM in the reference plots with increasing temperatures in late spring.

Discussion and Conclusions

Our results provide evidence that snow is a critical driver of winter ecosystem processes because of a decoupling of air and soil temperatures under the snowpack. The insulation offered by the snowpack protects subnivean biota. Snow removal altered the timing and magnitude of seasonal fluctuations of soil temperature and moisture, in turn influencing soil biological processes. Loss of snowpack resulted in greater soil frost in the treatment plots, including the formation of "concrete frost" due to rain-on-soil events during winter. Increased frost likely damaged fine roots and microbial populations, suggested by changes in nutrient availability and PNNM. These results reinforce the need to better understand the influence of climate change on soil dynamics in winter and spring, a period undergoing dynamic change.

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